REC'D 06 JUN 2005
WIPO PCT

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference WEJ504325-142	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. **PCT/NZ2004/000096**	International filing date *(day/month/year)* 21 May 2004	Priority date *(day/month/year)* 23 May 2003
International Patent Classification (IPC) or national classification and IPC **Int. Cl.** 7 H02J 3/00, 5/00, H02M 7/00, 11/00, H01F 38/14, B60L 9/00		
Applicant AUCKLAND UNISERVICES LIMITED et al		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. [X] *(sent to the applicant and to the International Bureau)* a total of 12 sheets, as follows:
      - [X] sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - [ ] sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. [ ] *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or table related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).
4. This report contains indications relating to the following items:

[X]	Box No. I	Basis of the report
[ ]	Box No. II	Priority
[ ]	Box No. III	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
[ ]	Box No. IV	Lack of unity of invention
[X]	Box No. V	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
[ ]	Box No. VI	Certain documents cited
[ ]	Box No. VII	Certain defects in the international application
[ ]	Box No. VIII	Certain observations on the international application

Date of submission of the demand 15 December 2004	Date of completion of the report 26 May 2005
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **MANO RAMACHANDRAN** Telephone No. (02) 6283 2166

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/NZ2004/000096

Box No. I **Basis of the report**

1. With regard to the language, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language ,
   which is the language of a translation furnished for the purposes of:

   ☐ international search (under Rules 12.3 and 23.1 (b))

   ☐ publication of the international application (under Rule 12.4)

   ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the elements of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

   ☐ the international application as originally filed/furnished

   ☒ the description:

   pages **1,7-19** as originally filed/furnished
   pages* **2-6** received by this Authority on **23 March 2005** with the letter of 23 March 2005
   pages* received by this Authority on with the letter of

   ☒ the claims:

   pages as originally filed/furnished
   pages* as amended (together with any statement) under Article 19
   pages* **20-26** received by this Authority on **23 March 2005** with the letter of 23 March 2005
   pages* received by this Authority on with the letter of

   ☐ the drawings:

   pages **1-5** as originally filed/furnished
   pages* received by this Authority on with the letter of
   pages* received by this Authority on with the letter of

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:

   ☐ the description, pages
   ☐ the claims, Nos.
   ☐ the drawings, sheets/figs
   ☐ the sequence listing (*specify*):
   ☐ any table(s) related to the sequence listing (*specify*):

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

   ☐ the description, pages
   ☐ the claims, Nos.
   ☐ the drawings, sheets/figs
   ☐ the sequence listing (*specify*):
   ☐ any table(s) related to the sequence listing (*specify*):

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

Box No. V **Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims **1-54**	**YES**
	Claims	**NO**
Inventive step (IS)	Claims **1-54**	**YES**
	Claims	**NO**
Industrial applicability (IA)	Claims **1-54**	**YES**
	Claims	**NO**

2. Citations and explanations (Rule 70.7)

None of the citations listed in the ISR discloses an ICPT pick-up resonant circuit as defined in claims 1, 28 and 37 where the ICPT pick-up circuit is selectively tuned and detuned depending on the sensed load condition. Claims 2-27, 29-36 and 38-54 appended to claims 1, 28 and 37 claim additional features and hence the invention defined in claims 1-54 is considered to be novel and involves an inventive step.

The closest art is found in the following documents:

(a) US 5450305 A

(b) US 5898579 A

frequency drift can significantly affect the tuning of pick-ups, especially those that use fixed frequency tuning. This reduces the ability of the system to effectively transfer power. Frequency drift can be caused by many factors: The most obvious is load change, but circuit parameter variations can also be significant.

One approach to compensate for frequency variations in the primary conductive path caused by load changes is to provide a plurality of individual capacitors and switch individual capacitors into or out of the primary power supply circuit. This approach has been posed in recently published United States patent application US2003/0210106. This has disadvantages in high Q systems because many capacitors are required. Also, load variations have to be limited to make the system function effectively.

Another approach is to use a more complex power supply, such as a third-generation (G3) supply, for the primary conductive path. This is expensive and such power supplies are not suited to miniaturisation.

OBJECT

It is an object of the present invention to provide a method of controlling, or apparatus for, an ICPT power supply which will ameliorate one or more of the disadvantages suffered by existing systems, or which will at least provide the public with a useful alternative.

BRIEF SUMMARY OF THE INVENTION

Accordingly in one aspect the invention provides An ICPT pick-up having a pick-up resonant circuit including a capacitive element and an inductive element adapted to receive power from a magnetic field associated with a primary conductive path to supply a load, sensing means to sense a condition of the load, and control means to selectively tune or de-tune the pick-up in response to the load sensed by the sensing means by varying the effective capacitance or inductance of the capacitive element or the inductive element of the pick-up circuit to control the transfer of power to the pick-up dependant on the sensed load condition.

The control means may include a reactive element and a switching means to allow the reactive element to be selectively electrically connected to the pick-up circuit. The control means is preferably operable to control the switching means so that the apparent

capacitance or inductance of the reactive element is varied to thereby tune or detune the pick-up circuit.

Phase sensing means may be provided to sense the phase of a voltage or current in the resonant circuit whereby the control means may actuate the switching means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed phase.

The reactive element may comprise an inductor, and the phase sensing means can sense a voltage in the resonant circuit and the switch control means is operable to switch the second switching means to electrically connect or disconnect the inductor to or from the resonant circuit a predetermined time period after a sensed voltage zero crossing.

The reactive element may alternatively comprise a capacitor, and the phase sensing means can sense a voltage in the resonant circuit and the switch control means is operable to switch the second switching means to electrically connect or disconnect the inductor to or from the resonant circuit a predetermined time period after a sensed voltage zero crossing.

Frequency sensing means are preferably provided to sense the frequency of the resonant circuit. This may allow the control means may actuate the switch means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

The phase sensing means may also sense the frequency of the resonant circuit.

The control means may actuate the switch means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

Where the reactive element comprises an inductor, the control means is adapted to activate the second switching means to connect the inductor to the resonant circuit after the predetermined time period following a voltage zero crossing has elapsed, and allow the second switching means to be deactivated when the voltage again reaches substantially zero. The control means is capable of varying the predetermined time period

PCT/NZ2004/000096
Received 23 March 2005

between substantially 0 electrical degrees and substantially 180 electrical degrees, and most preferably between substantially 90 electrical degrees and substantially 150 electrical degrees.

Where the reactive element comprises an capacitor, the control means is adapted to activate the second switching means to disconnect the capacitor from the resonant circuit after the predetermined time period following a voltage zero crossing has elapsed. The control means is capable of varying the predetermined time period between substantially 0 electrical degrees and substantially 90 electrical degrees.

In a further aspect the invention provides An ICPT system including:

a. A power supply comprising a resonant converter to provide alternating current to a primary conductive path of the ICPT system;
b. One or more secondary pick-ups, each pick-up having a pick-up resonant circuit including a capacitive element and an inductive element adapted to receive power from a magnetic field associated with a primary conductive path to supply a load, sensing means to sense a condition of the load, and control means to selectively tune or de-tune the pick-up in response to the load sensed by the sensing means by varying the effective capacitance or inductance of the capacitive element or the inductive element of the pick-up circuit to control the transfer of power to the pick-up dependant on the sensed load condition.

The primary conductive path comprises one or more turns of electrically conductive material, and may be provided beneath a substantially planar surface.

The primary conductive path may include at least one region about which there is a greater magnetic field strength than one or more other regions of the path. The path may achieve this by having one or more lumped inductances or one or more distributed inductances.

In a preferred embodiment the primary conductive path is mounted adjacent to an amorphous magnetic material to provide a desired magnetic flux path.

The pick-up may also include an amorphous magnetic material adjacent to the pick-up coil

PCT/NZ2004/000096
Received 23 March 2005

to provide a desired magnetic flux path.

In a still further aspect the invention provides a method for controlling power drawn by an ICPT pick-up, the method including the steps of sensing a load condition of the pick-up, and selectively tuning or detuning the pick-up circuit depending upon the sensed load condition.

The step of tuning or detuning the pickup circuit preferably includes moving the resonant frequency of the pick-up circuit toward or away from a tuned condition. This is most preferably achieved by controlling a variable capacitor or inductor.

The method may include the step of sensing the frequency of a current or voltage in the resonant circuit. The sensed frequency may then be compared with a nominal frequency for the resonant circuit and tuning or de-tuning toward or away from the nominal frequency dependant on the sensed load.

The reactive element may be selectively switched into or out of the resonant circuit to alter the apparent inductance or capacitance of the reactive element to thereby tune or de-tune the resonant circuit.

In a preferred embodiment the method includes sensing the phase of a voltage or current in the resonant circuit and electrically connecting or disconnecting the reactive element to or from the resonant circuit dependant on the sensed phase. The reactive element may be electrically connected to the resonant circuit a predetermined time period after a sensed voltage zero crossing.

The method may include sensing the frequency of the resonant circuit activating a switching means to electrically connect or disconnect the reactive element to or from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

The sensed frequency may be compared with a nominal frequency to allow variation of the predetermined time period to tune the resonant circuit toward or away from the nominal frequency.

If the reactive element comprises an inductor, then the method may include activating a

PCT/NZ2004/000096
Received 23 March 2005

switching means to connect the reactive element to the resonant circuit after the predetermined time period following a voltage zero crossing has elapsed, and allowing the second switching means to be deactivated when the voltage again reaches substantially zero. The predetermined time period is preferably selected from a range between substantially 0 electrical degrees and substantially 180 electrical degrees, and most preferably from a range between substantially 90 electrical degrees and substantially 150 electrical degrees.

If the reactive element comprises a capacitor, then the method may include activating a switching means to electrically disconnecting the reactive element from the resonant circuit a predetermined time period after a sensed voltage zero crossing. The predetermined time period is preferably selected from a range between substantially 0 electrical degrees and substantially 90 electrical degrees.

The invention may also broadly consist in any new part feature or element disclosed herein, or any new combination of such parts, features or elements.

DRAWING DESCRIPTION

One or more examples of an embodiment of the invention will be described below with reference to the accompanying drawing in which:

Figure 1	is a diagram of the basic structure of a known ICPT system,
Figure 2	is a diagram of a pick-up circuit topology including a variable inductor for an ICPT power supply,
Figure 3a -3c	show current waveforms of the controlled inductor of Figure 2 with reference to the pick-up coil voltage,
Figure 4	is a plot of equivalent inductance change against delay angle for the controlled inductor of Figure 2,
Figure 5	is a diagram of a pick-up circuit topology including a variable capacitor for an ICPT power supply,
Figure 6	is a simplified circuit diagram of the circuit of Figure 5,
Figure 7	is a graph of equivalent capacitance against Q factor for the circuit of Figure 6,
Figures 8a-8b	show the voltage and current waveforms relating to the controlled variable capacitor of Figure 5,
Figure 9	is a perspective view of a device including a lumped primary conductive

PCT/NZ2004/000096
Received 23 March 2005

Claims

1. An ICPT pick-up having a pick-up resonant circuit including a capacitive element and an inductive element adapted to receive power from a magnetic field associated with a primary conductive path to supply a load, sensing means to sense a condition of the load, and control means to selectively tune or de-tune the pick-up in response to the load sensed by the sensing means by varying the effective capacitance or inductance of the capacitive or the inductive element of the pick-up circuit to control the transfer of power to the pick-up dependant on the sensed load condition.

2. A pick-up as claimed in claim 1 wherein the control means includes a reactive element and a switching means to allow the reactive element to be selectively electrically connected to the pick-up circuit.

3. A pick-up as claimed in claim 2 wherein the control means is operable to control the switching means so that the apparent capacitance or inductance of the reactive element is varied to thereby tune or detune the pick-up circuit.

4. A pick-up as claimed in any one of claims 1 to 3 wherein the sensing means senses the power required by the load.

5. A pick-up as claimed in any one of claims 2 to 4 including phase sensing means to sense the phase of a voltage or current in the resonant circuit whereby the control means may actuate the switching means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed phase.

6. A pick-up as claimed in claim 5 wherein the reactive element comprises an inductor, the phase sensing means senses a voltage in the resonant circuit and the switch control means is operable to switch the switching means to electrically connect or disconnect the inductor to or from the resonant circuit a predetermined time period after a sensed voltage zero crossing.

7. A pick-up as claimed in claim 4 or claim 5 including frequency sensing means to sense the frequency of the resonant circuit whereby the control means may actuate the switch means to allow the reactive element to be electrically connected to or

PCT/NZ2004/000096
Received 23 March 2005

disconnected from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

8. A pick-up as claimed in claim 4 or claim 5 wherein the phase sensing means sense the frequency of the resonant circuit whereby the control means may actuate the switch means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

9. A pick-up as claimed in any one of claims 6 to 8 wherein the control means is adapted to activate the second switching means to connect the inductor to the resonant circuit after the predetermined time period following a voltage zero crossing has elapsed, and allow the switching means to be deactivated when the voltage again reaches substantially zero.

10. A pick-up as claimed in any one of claims 6 to 9 wherein the control means is capable of varying the predetermined time period between substantially 0 electrical degrees and substantially 180 electrical degrees.

11. A pick-up as claimed in any one of claims 6 to 9 wherein the control means is capable of varying the predetermined time period between substantially 90 electrical degrees and substantially 150 electrical degrees.

12. A pick-up as claimed in any one of claims 6 to 11 wherein the inductor is connected in parallel with a tuning capacitor of the resonant circuit.

13. A pick-up as claimed in any one of claims 6 to 12 wherein the inductor has two terminals and the second switching means comprise two controllable semiconductor switching elements, one switching element being connected between each terminal and the resonant circuit.

14. A pick-up as claimed in claim 13 wherein each switching element has an anti-parallel diode connected thereacross.

15. A pick-up as claimed in claim 13 or claim 14 wherein the semiconductor switch elements comprise IGBT's, MOSFETS, MCT's, BJT's.

PCT/NZ2004/000096
Received 23 March 2005

16. A pick-up as claimed in claim 3 wherein the inductor comprises the pick-up coil.

17. A pick-up as claimed in claim 5 wherein the reactive element comprises a capacitor, the phase sensing means senses a voltage in the resonant circuit, and the switch control means is operable to switch the switching means to electrically connect or disconnect the capacitor to or from the resonant circuit a predetermined time period after a sensed voltage zero crossing.

18. A pick-up as claimed in claim 17 including frequency sensing means to sense the frequency of the resonant circuit whereby the control means may actuate the switch means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

19. A pick-up as claimed in claim 17 wherein the phase sensing means sense the frequency of the resonant circuit whereby the control means may actuate the switch means to allow the reactive element to be electrically connected to or disconnected from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

20. A pick-up as claimed in any one of claims 17 to 19 wherein the control means is adapted to activate the switching means to disconnect the capacitor from the resonant circuit after the predetermined time period following a voltage zero crossing has elapsed.

21. A pick-up as claimed in any one of claims 17 to 20 wherein the control means is capable of varying the predetermined time period between substantially 0 electrical degrees and substantially 90 electrical degrees.

22. A pick-up as claimed in any one of claims 17 to 21 wherein the capacitor is connected in parallel with a tuning capacitor of the resonant circuit.

23. A pick-up as claimed in claim 22 wherein the capacitance of the capacitor is substantially equal to the capacitance of the tuning capacitor.

PCT/NZ2004/000096
Received 23 March 2005

24. A pick-up as claimed in any one of claims 17 to 23 wherein the capacitor has two terminals and the switching means comprise two controllable semiconductor switching elements, one switching element being connected between each terminal and the resonant circuit.

25. A pick-up as claimed in claim 24 wherein each switching element has an anti-parallel diode connected thereacross.

26. A pick-up as claimed in claim 24 or claim 25 wherein the semiconductor switch elements comprise IGBT's, MOSFETS,or BJT's.

27. A pick-up as claimed in any one of claims 17 to 21 wherein the variable reactance comprises the tuning capacitor of the resonant circuit.

28. An ICPT system including:

a. A power supply comprising a resonant converter to provide alternating current to a primary conductive path of the ICPT system;
b. One or more secondary pick-ups, each pick-up having a pick-up resonant circuit including a capacitive element and an inductive element adapted to receive power from a magnetic field associated with a primary conductive path to supply a load, sensing means to sense a condition of the load, and control means to selectively tune or de-tune the pick-up in response to the load sensed by the sensing means by varying the effective capacitance or inductance of the capacitive element or the inductive element of the pick-up circuit to control the transfer of power to the pick-up dependant on the sensed load condition.

29. An ICPT system as claimed in claim 28 wherein the primary conductive path comprises one or more turns of electrically conductive material.

30. An ICPT system as claimed in claim 29 wherein the primary conductive path is provided beneath a substantially planar surface.

31. An ICPT system as claimed in claim 28 wherein the primary conductive path includes at least one region about which there is a greater magnetic field strength than one or more other regions of the path.

PCT/NZ2004/000096
Received 23 March 2005

32. An ICPT system as claimed in claim 28 wherein the primary conductive path includes one or more lumped inductances or one or more distributed inductances.

33. An ICPT system as claimed in any one of claims 28 to 32 wherein the primary conductive path is mounted adjacent to an amorphous magnetic material to provide a desired magnetic flux path.

34. An ICPT system as claimed in any one of claims 28 to 33 wherein the pick-up includes an amorphous magnetic material adjacent to the pick-up coil to provide a desired magnetic flux path.

35. An ICPT system as claimed in any one of claims 28 to 34 wherein the pick-up is battery-free.

36. An ICPT system as claimed in any one of claims 28 to 34 wherein the pick-up includes a super-capacitor.

37. A method for controlling power drawn by an ICPT pick-up, the method including the steps of sensing a load condition of the pick-up, and selectively tuning or detuning the pick-up circuit depending upon the sensed load condition.

38. A method as claimed in claim 37 wherein the step of tuning or detuning the pickup circuit includes moving the resonant frequency of the pick-up circuit toward or away from a tuned condition.

39. A method as claimed in claim 37 or claim 38 wherein the step of tuning or detuning the pick-up circuit includes the step of controlling a variable capacitor or inductor.

40. A method as claimed in any one of claims 37 to 39 including the step of sensing the frequency of a current or voltage in the resonant circuit.

41. A method as claimed in claim 40 including the step of comparing the sensed frequency with a nominal frequency for the resonant circuit and tuning or de-tuning toward or away from the nominal frequency dependant on the sensed load.

PCT/NZ2004/000096
Received 23 March 2005

42. A method as claimed in any one of claims 37 to 41 including the steps of selectively switching a reactive element into or out of the resonant circuit to alter the apparent inductance or capacitance of the reactive element to thereby tune or de-tune the resonant circuit.

43. A method as claimed in claim 42 including sensing the phase of a voltage or current in the resonant circuit and electrically connecting or disconnecting the reactive element to or from the resonant circuit dependant on the sensed phase.

44. A method as claimed in claim 43 wherein the phase of a voltage is sensed and the reactive element is electrically connected to the resonant circuit a predetermined time period after a sensed voltage zero crossing.

45. A method as claimed in any one of claims 42 to 44 including sensing the frequency of the resonant circuit activating a switching means to electrically connect or disconnect the reactive element to or from the resonant circuit dependant on the sensed frequency to alter the natural resonant frequency of the resonant circuit.

46. A method as claimed in any one of claims 42 to 45 including comparing the sensed frequency with a nominal frequency and varying the predetermined time period to tune the resonant circuit toward or away from the nominal frequency.

47. A method as claimed in any one of claims 42 to 46 including activating a switching means to connect the reactive element to the resonant circuit after the predetermined time period following a voltage zero crossing has elapsed, and allowing the second switching means to be deactivated when the voltage again reaches substantially zero.

48. A method as claimed in any one of claims 42 to 47 including selecting the predetermined time period from a range between substantially 0 electrical degrees and substantially 180 electrical degrees.

49. A method as claimed in any one of claims 42 to 47 including selecting the predetermined time period from a range between substantially 90 electrical degrees and substantially 150 electrical degrees.

PCT/NZ2004/000096
Received 23 March 2005

50. A method as claimed in claim 43 including sensing the phase of a voltage and electrically disconnecting the reactive element from the resonant circuit a predetermined time period after a sensed voltage zero crossing.

51. A method as claimed in claim 50 wherein the reactive element comprises a capacitor and the predetermined time period is selected from a range between substantially 0 electrical degrees and substantially 90 electrical degrees.

52. A pick-up substantially as herein described with reference to any one of the embodiments illustrated in the accompanying drawings.

53. An ICPT system substantially as herein described with reference to any one of the embodiments illustrated in the accompanying drawings.

54. A method for controlling power substantially as herein described with reference to any one of the embodiments illustrated in the accompanying drawings.

TSPEC4309854